Chapter 9

Disposal of High-Level Radioactive Waste in Finland

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Abstract. Detailed site investigations are under way on three candidate sites with the aim of selecting the site for a final repository for spent fuel in 2000. In May 1995, the Finnish nuclear power companies, IVO and TVO, made an agreement on the establishment of a joint company for final disposal of spent fuel in Finland, and the new company, Posiva, has taken over the work so far conducted solely by TVO for the disposal of spent fuel. After site selection, the first exploratory shaft will be constructed on the nominated site, and the actual construction of the repository will be started in the 2010's. According to the time schedule set by the Finnish Government in 1983, the repository must be available in 2020.

9.1 Introduction

About one third of the electricity produced in Finland is currently generated by nuclear power plants. There are two pressurized water reactors (PWR) with a combined capacity of 890 MWe at Loviisa and two boiling water reactors (BWR) with a combined capacity of 1420 MWe at Olkiluoto. The PWR power plant is owned and operated by Imatran Voima Oy (IVO), the BWR plant, by Teollisuuden Voima Oy (TVO).

According to Finnish legislation the nuclear power producer is solely responsible for the management and disposal of all radioactive wastes, including the spent fuel. Funds for future waste handling and disposal are included in the price of electricity and are set aside in a special fund under the authority of the Ministry of Trade and Industry (KTM). The Government has set the basic guidelines for waste management in a resolution of 1983 concerning the goals for research and planning in the area. These guidelines have been further focused and updated by decisions of KTM. In these guidelines and decisions, time schedules are set for construction of the final disposal facilities, and, in addition, some general principles are given for the research and development (R&D) programme.

The Loviisa power plant units are based on the Russian VVER-440 design and, in connection with the purchase of the reactors, the utility also made contractual arrangements for the entire fuel cycle service from the former USSR. This included both the supply of fresh fuel and the return of spent fuel back to the supplier. After the break-up of the USSR, the contract was endorsed by the Russian Government and the return shipments of spent fuel continued on a regular basis.

In late 1994, however, the Finnish Parliament passed an amendment to the Nuclear Energy Act which prohibits all exports and imports of nuclear waste, including spent fuel. Atwo-year transition period was granted for IVO’s shipments of spent fuel to Russia, but from 1997 on, the spent fuel from Loviisa nuclear power station will be retained for final disposal in Finland.

In view of this new situation, the two nuclear power companies, IVO and TVO, started discussions on cooperation for a common disposal facility for their spent fuel. The companies already coordinated their nuclear waste research through the Nuclear Waste Commission of the Finnish Power Companies (YJT), and the question was how this cooperation could be enhanced in a joint undertaking.

These discussions were concluded in May 1995 in an agreement on the establishment of a joint company for the final disposal of spent fuel in Finland. From the beginning of 1996, the new company, Posiva, takes care of all the planning, research and development work needed and will later construct and operate the encapsulation facility and the deep underground repository. The mission neither includes interim storage of spent fuel nor the disposal of low- and intermediate-level operating wastes, for which the two power companies will

Figure 9.1. Final disposal facility for spent fuel.

have separate disposal facilities; TVO has had a repository in operation since 1992, and IVO has a repository under construction.

The programme for the final disposal of spent fuel will proceed along the time schedules originally set by the Government for the disposal of spent fuel from the TVO power plant. The plan is to dispose of the spent fuel directly, without reprocessing. According to the time schedule, the final repository for spent fuel must be available in 2020, and the site for the repository has to be selected by the end of the year 2000. Accordingly, the construction of the repository will be started in the 2010's. The total amount of spent fuel to be disposed of in the repository will be about 2500 tHM.

9.2 PROGRAMME STATUS

The technical plan for final disposal is based on the KBS-3 concept[1], but a new design for canisters has been introduced by TVO. Complete technical plans for disposal, together with a safety assessment, were submitted to the authorities at the end of 1992[2].

The concept consists of emplacing the packaged spent fuel in vertical holes in tunnels that have been excavated deep in the bedrock (Fig. 9.1). The repository depth will be somewhere between 300 m and 800 m depending on the geology and other characteristics of the site and also on various safety-related considerations. Fig. 9.1 depicts an idealized situation; in practice the tunnel network will be adapted to local bedrock features and may be split in several parts to avoid crossing major fracture zones. The packaging of the waste will take place at an encapsulation plant which will be constructed at the repository site at the surface. An elevator can then be used to transfer the waste packages directly to the repository.

In the new canister concept, the "Advanced Cold Pro-

Figure 9.2. Advanced cold process (ACP) canister for direct disposal of spent fuel.

cess" (ACP) canister is a composite canister consisting of an inner container of steel as a load-bearing element and an outer container of oxygen-free copper to provide a shield against corrosion (Fig. 9.2). The wall thicknesses are 60 mm for the copper canister and 55 mm for the steel canister. The original canister design was only for 9 BWR fuel assemblies from the TVO power plant, but it has been modified for the hexagonal fuel elements from the Loviisa PWRs assemblies as well. The empty space in the canister can be filled with a granular material, such as lead shot, glass beads or quartz sand, but other alternatives are also being considered. Depending on the filling material used, the total weight of the full canister will be 14 to 20 tonnes.

The name of the canister design (Advanced Cold Process Canister) is due to the principal driving force behind the development work. The original KBS copper canister design assumes a lead casting to fill the voids between the fuel assemblies and canister walls. Since the lead casting would probably be the technically most difficult phase in the encapsulation process, the question was raised whether the use of molten lead could be avoided by replacing it with some "cold" material. However, the copper canister without the cast lead might not meet the mechanical requirements, mainly because of the creep properties of copper. In the ACP canister, the use of molten lead has been avoided because the mechanical strength is now provided by the inner steel canister.

For the selection of the repository site, the strategy is to find a "good enough" site, i.e., a site that offers sufficient characteristics to ensure the long-term safety of disposal. It is considered both unnecessary and unrealistic to try searching for the "best" site.

The site selection process for a repository started in 1983 with a country-wide survey of the principal geological features in Finland. The approach used for local-

Figure 9.3. Principle site selection for the spent fuel repository.

ization of candidate sites was based on the crush-tectonic block structure of the Finnish bedrock. All the bedrock in Finland is broken down into blocks separated by regional crush (or shear) zones whose length may be dozens of kilometres (Fig. 9.3). These, in turn, are divided into smaller sectors according to the presence of smaller fracture zones. What is important for repository siting is that the rock response to future changes in stress conditions be mainly confined to these crush zones, while the rock outside the fracture zones remains basically unaffected. This will ensure sufficient stability for the host rock of the repository.

A total of 327 large regional blocks were identified in the first country-wide screening of the bedrock features. Mainly for land-use restrictions and other geographic reasons, the number of possible regions was later reduced to 61, among which 134 smaller areas were selected as candidates for investigation sites. In 1987, five areas were selected for preliminary site investigations. These are situated in different parts of the country and represent somewhat different geologic histories (Fig. 9.4). In addition to geologic factors, geographic factors, land ownership and transport and other infrastructure considerations were taken into account in the selection of the sites for preliminary site investigations. One of the areas chosen for investigations is the Olkiluoto island in Eurajoki where the TVO power plant is also situated.

The principal goal of the preliminary site investigations was to characterise the candidate sites to the extent needed to judge whether the preconception on their suitability for hosting a repository could be confirmed. The investigations at each site comprised drillings and samplings, various geophysical, geohydraulic, rock-mechanical, chemical and mineralogical studies, and modelling of the bedrock structure and groundwater

Figure 9.4. Preliminary site investigations areas in 1987-1992. Kuhmo, Konginkangas (since 1993 a part of Aanekoski town) and Eurajoki were selected in 1992 for detailed site investigations.

flow in the area. At least five deep (500 to 1000 m) cored boreholes were drilled in addition to a number of shallow boreholes. The results of the preliminary site investigations were submitted to the authorities at the end of 1992[3]. These results did not reveal any surprises in relation to expectations; no exceptional features were detected that would compromise the siting of the repository within the area studied.

In parallel with these site investigations, a safety assessment ("TVO-92") was carried out[4]. The analysis used the data from the preliminary site investigations but was not specific as to any of the sites studied. The principle has been to select the parameters and assumptions in such a way that a location could be found at each of the sites with certainly more favourable conditions than were assumed in the safety assessment. For example, very conservative assumptions were made with regard to groundwater flow at the repository site. It was assumed in the reference scenario of the analysis that the groundwater transit time from the repository to the biosphere is only five years.

The safety analysis includes a detailed groundwater flow analysis for a hypothetical repository located at one of the investigation sites. Figure 9.5 depicts how the repository could be adapted to the local fracture zones around the deep drillholes. It is seen that two fracture zones, R11 and R15, cross the repository area. If the transmissivity of the repository (together with the excavation damage zones) were high in relation to the surrounding rock, then in principle, a U-tube flow condition could form. Although, in reality, this would be very unlikely, such a situation has been taken as the basis in the reference scenario of the safety assessment.

The number of scenarios was kept small by restricting the analysis to a set of bounding cases that, nevertheless,

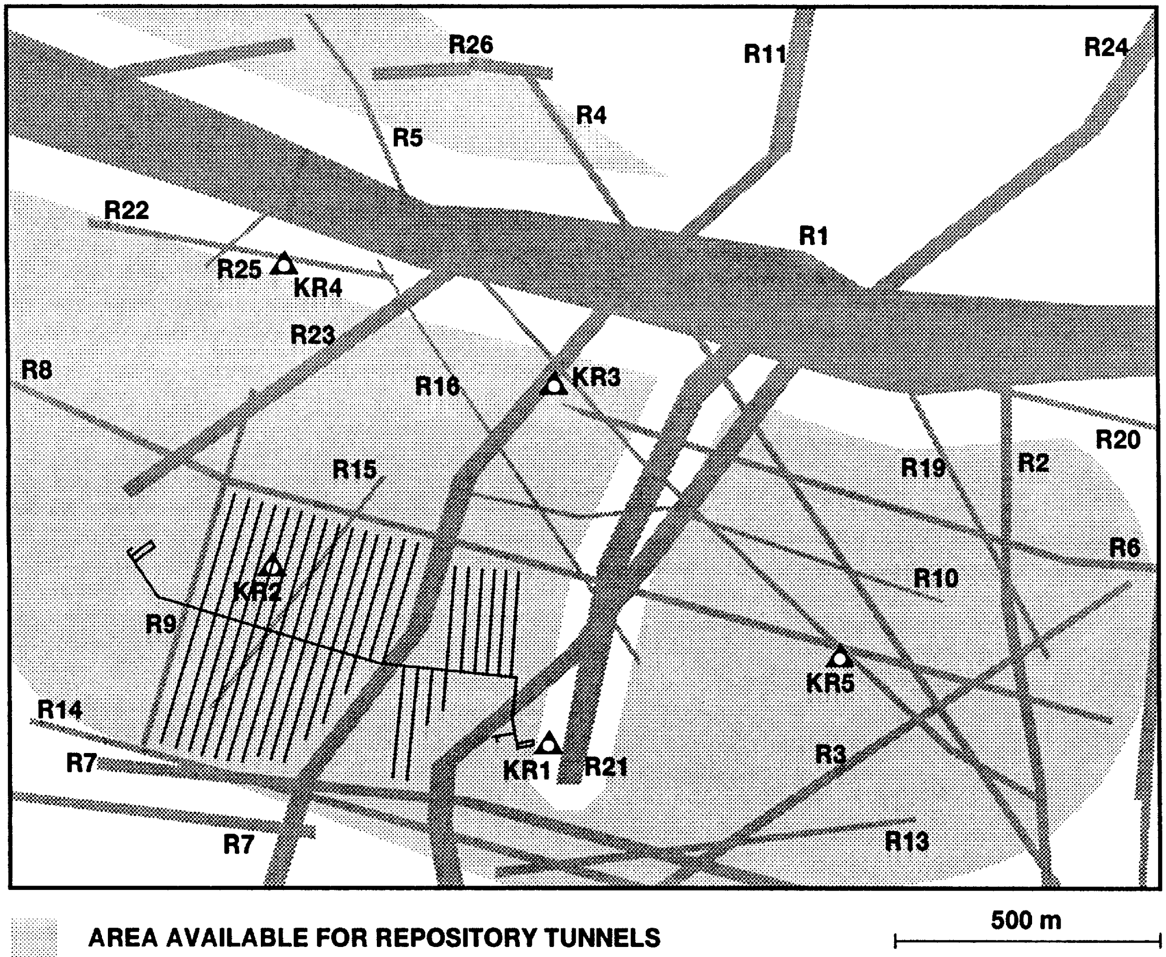

Figure 9.5. Adaptation of the repository to local bedrock features (example from Hyrynsalmi investigation site).

cover all reasonably conceivable situations. Aside from the base case (the conditions in the vicinity of the repository remain basically as they are now), the analysis has been centred on the reference case, which simply assumes a total loss of canisters after 10,000 years from the time of deposition. This simplification has helped to greatly reduce the number of different scenarios in the analysis.

Despite the conservative data and concepts adopted, the safety analysis shows that the criteria proposed by the Nordic safety authorities in 1993 can easily be met[5]. At the same time, the analysis shows that safety is ensured no matter which one of the candidate sites is chosen.

In addition to geology and long-term safety, various other aspects of the candidate sites were assessed, such as local infrastructure and available means and routes of transportation and constructability. It turned out that there were no decisive differences between the sites studied. However, for focusing the field work further, the decision was made to restrict the detailed investigations to three candidate sites: Eurajoki, Kuhmo and Äänekoski (formerly Konginkangas). The choice was mainly based on the praciticality of investigations; it was evident that at the two discarded sites (Sievi, Hyrynsalmi), investigations would have to be extended over a larger area than was well covered by the drillings during the preliminary site investigations. At the three selected sites, the future investigations could most efficiently make use of the already existing boreholes and other data.

9.3 FUTURE INVESTIGATIONS

Detailed site investigations are now under way on the three candidate sites with the objective of establishing the database needed for site selection in the year 2000.

In 1994, TVO also conducted a prefeasibility study in Kannonkoski, a neighbouring municipality to Äänekoski, as a possible site for the repository. On the basis of a geologic survey and other considerations, it was concluded that Kannonkoski could be an alternative to Äänekoski, in case there was need to search for new candidate sites; but for the moment, the three candidate sites are considered sufficient. Now, after the decision by IVO and TVO to work toward a joint repository, a similar prefeasibility study is being conducted at Loviisa, the site of the IVO power plant. The need for drilling and other field work at Kannonkoski or Loviisa will be considered at the end of 1996, when an interim report of all studies and investigations conducted since 1992 will be submitted to authorities.

For site selection, a site-specific safety analysis will be carried out for the nominated site and the technical concept by the end of 2000. Updated technical plans will be presented, including preliminary layouts adapted to the local geologic features. Later, in the early 2000's the first exploratory shaft will be constructed at the site, and the construction work for the repository itself can be started after 2010, assuming a favorable development with the licensing.

For drilling and other surface-based site investigations, the only license required so far is permission from the land-owner, who, in the case of the candidate sites, is the state or the power companies themselves. However, construction of the repository is possible only after a positive decision by the Parliament, and such decision can only be made if the local municipality approves the siting proposal. Since the local veto cannot be overridden, public acceptance will be crucial for the successful implementation of the plans. According to the present time schedule, the municipality will have to define its position on the proposed siting in about ten years. To gain local support for the plan will be a major challenge in providing for the ultimate disposal of nuclear wastes in Finland.

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